

43.6°C

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Mathematics

A key enabler for Digital Twins

Dirk Hartmann, 17 July 2019

VISIT...

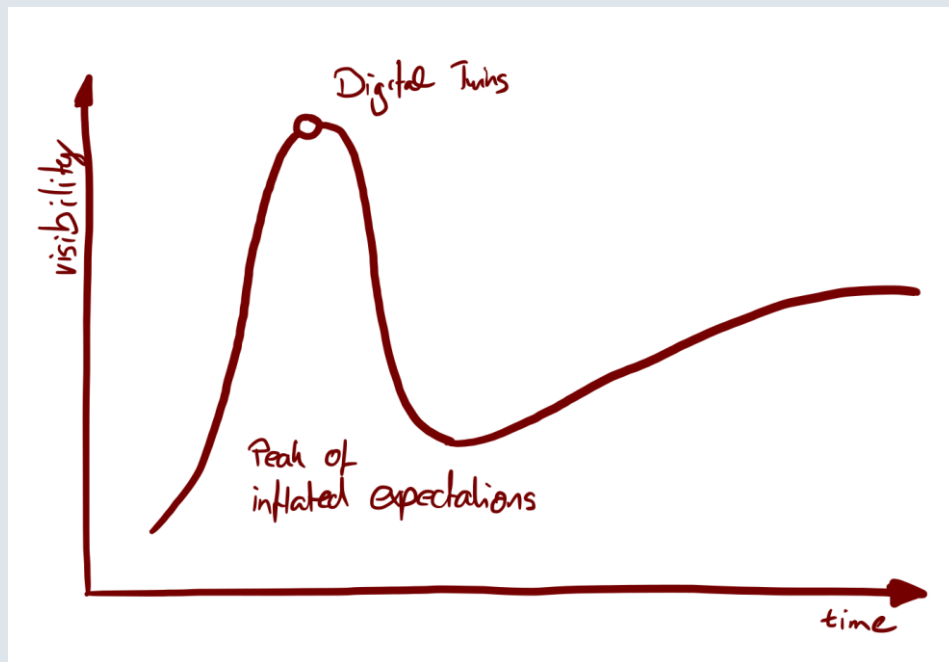
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Digital twin in a nutshell

Digital twins – More than a digital hype?

Gartner Hype Cycle for emerging technologies, 2018



Source: K. Panetta (2018): <https://www.gartner.com/smarterwithgartner/5-trends-emerge-in-gartner-hype-cycle-for-emerging-technologies-2018>, Gartner



Deloitte:

[Expecting digital twins](#), 2018



Goldmann Sachs:

[Double vision: Using 'digital twins' to pair virtual and physical worlds](#), 2018



MITsloan review:

[Short video series on digital twin](#), 2018



Economist:

[Millions of things will soon have digital twins](#), 2017



Forbes:

[Why digital twins should be the CEO's best friend](#), 2018

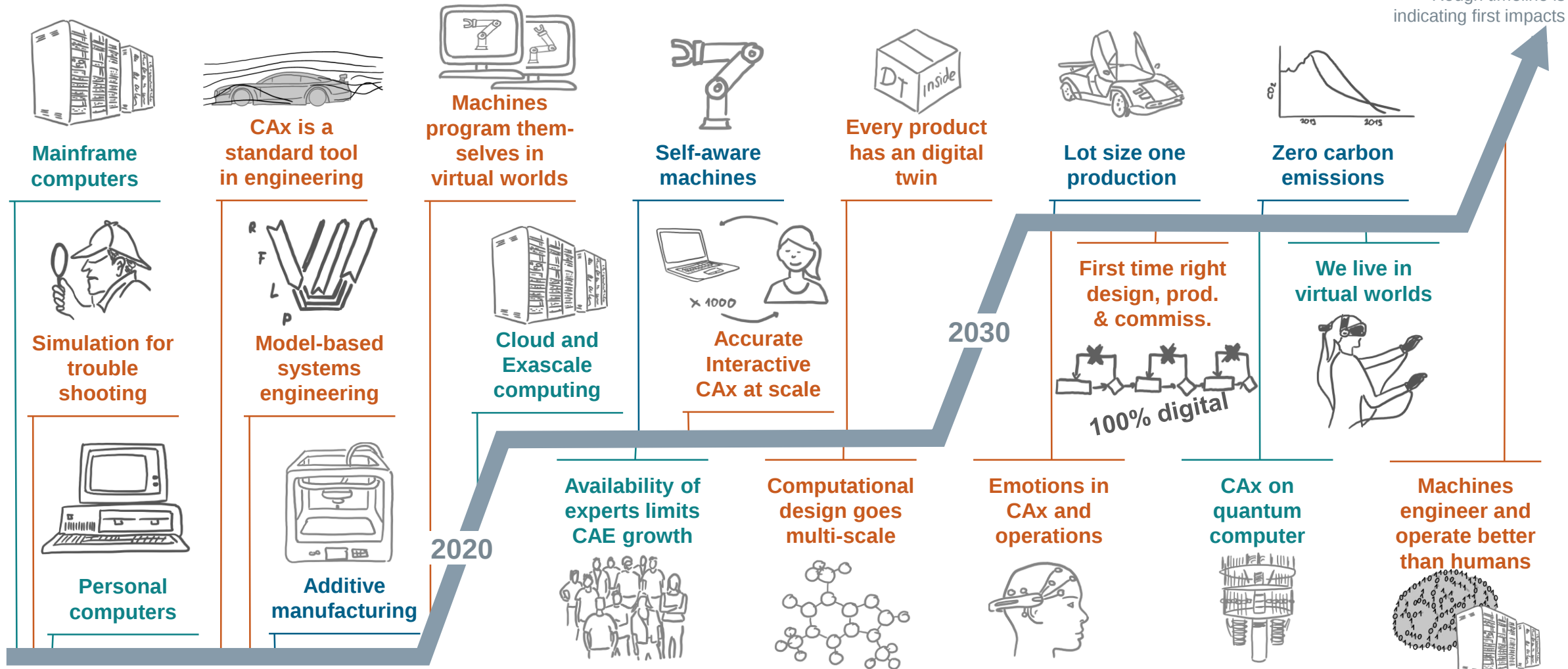
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Digitalization and associated innovations will change everything, selected trends affecting simulation and digital twin.

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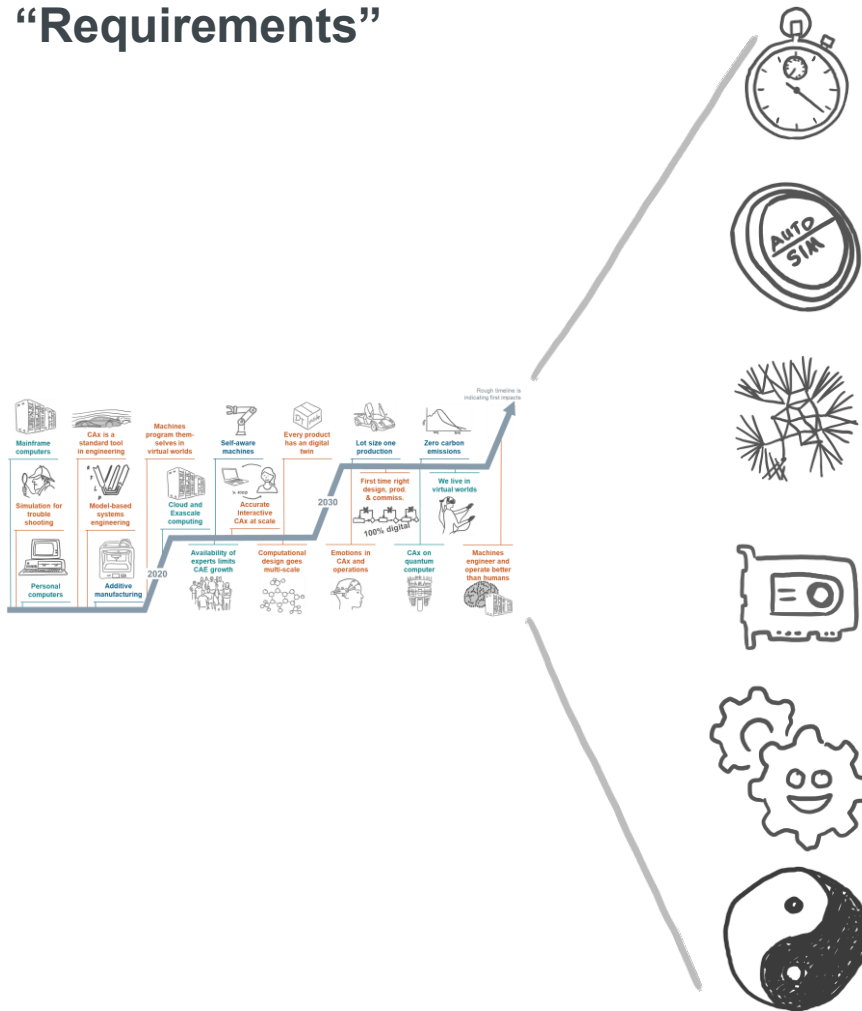
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Rough timeline is indicating first impacts



Therefore, simulation and digital twins ...

“Requirements”



... must adapt speed and accuracy to purpose

... must be self-aware, self-adjusting, and autonomous

... must interact and adapt in heterogeneous contexts

... must adapt to hardware architectures

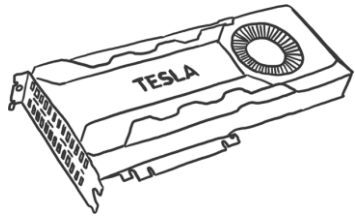
... must be user friendly

... must be specific and synchronized

Major leaps in electronics, mathematics, and computer science allow to challenge established paradigms.



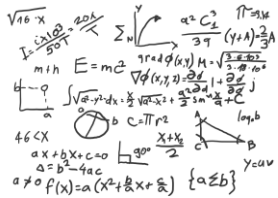
Technology Push / Major Game Changers



Computational power is exploding - *More than Moore's Law*

Computer and hardware architectures beyond scaling of chip performance and cloud, e.g. GPUs, reconfigurable computing, ubiquitous computing.

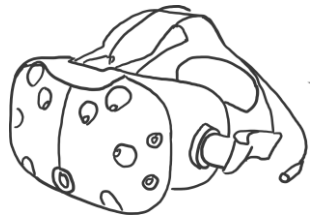
Source: International Technology Roadmap for Semiconductors (2007), [White Paper](#)



Major breakthrough in mathematics and computer science achieved

Exponential capability growth contributing significantly to efficiency, scalability, and usability of (simulation) model-based as well as data-based approaches.

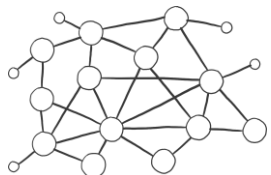
Source: SIAM CSE (2016), [White Paper](#)



Virtual and mixed reality is entering professional market

Consumer technologies such as virtual or mixed reality becoming mainstream in industry and driving democratization of formerly expert centric tools.

Source: Goldman Sachs (2016), [Virtual and Augmented Reality](#)



Semantic standards and knowledge graphs are maturing

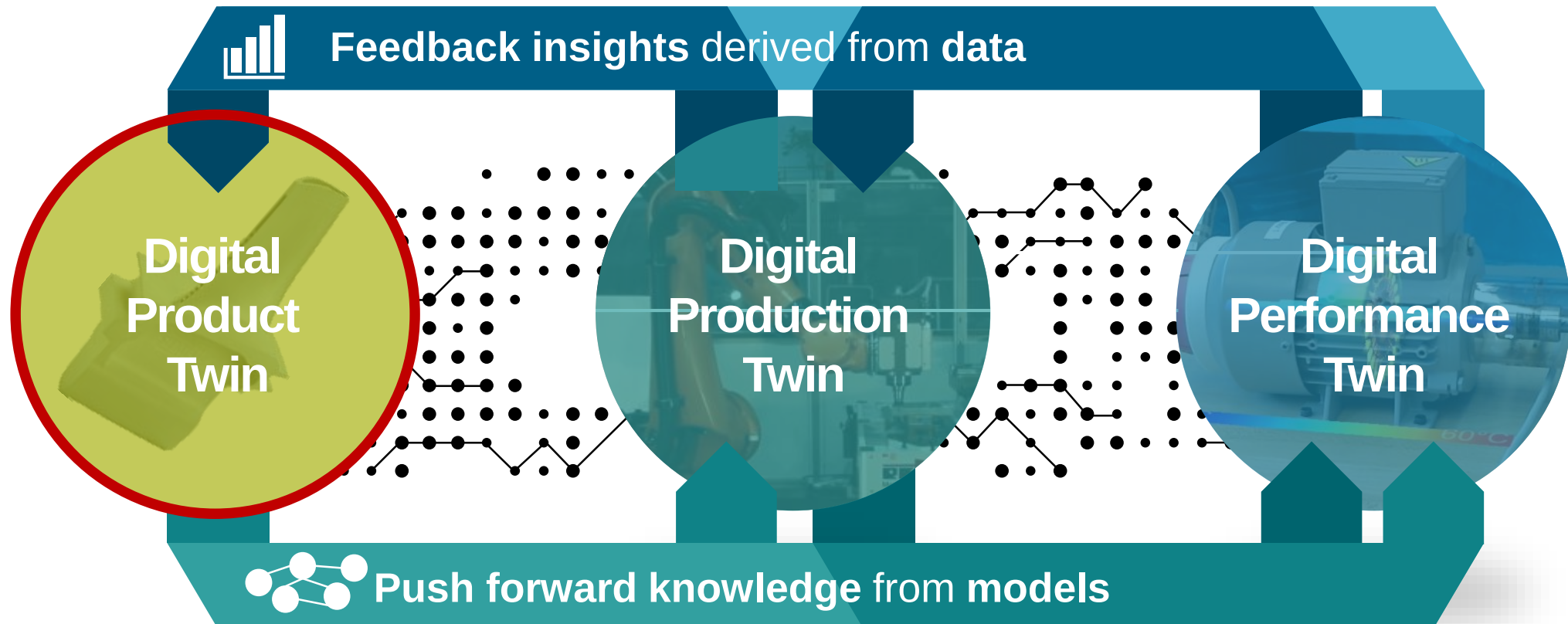
Knowledge graphs are entering rapidly the industrial domain allowing for efficient realization of ontologies putting semantic information access to a new level beyond general purpose interoperable standards.

Source: Forbes (2018), [Knowledge Graphs](#)

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Digital product twin democratizes design

Digital twins improve
development, production / construction, and operation.



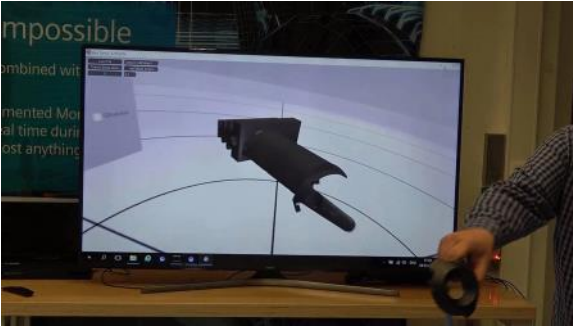
Digital product twin ...
... democratizes design.

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Source: new.siemens.com

Digital product twin democratizes design.



Source: new.siemens.com



Efficient discretization techniques

allowing lean codes, efficient memory access, easy parallelization, and fast transfer to novel architectures



Optimal solver technology

exploiting achievements in computational science and engineering driving exponential growth in algorithmic performance



Hardware-aware algorithms

leveraging next generation compute architectures, e.g. GPUs, TPUs, and reconfigurable computing

- **1000x faster** than today's solvers
- 10x faster concept development **boosting innovation**
- **Democratize CAE** with 50M unaddressed users today

Sources: S. Gavranovic, D. Hartmann, U Wever (2015): *Topology Optimization using GPGPU*, [EUROGEN 2015](#)

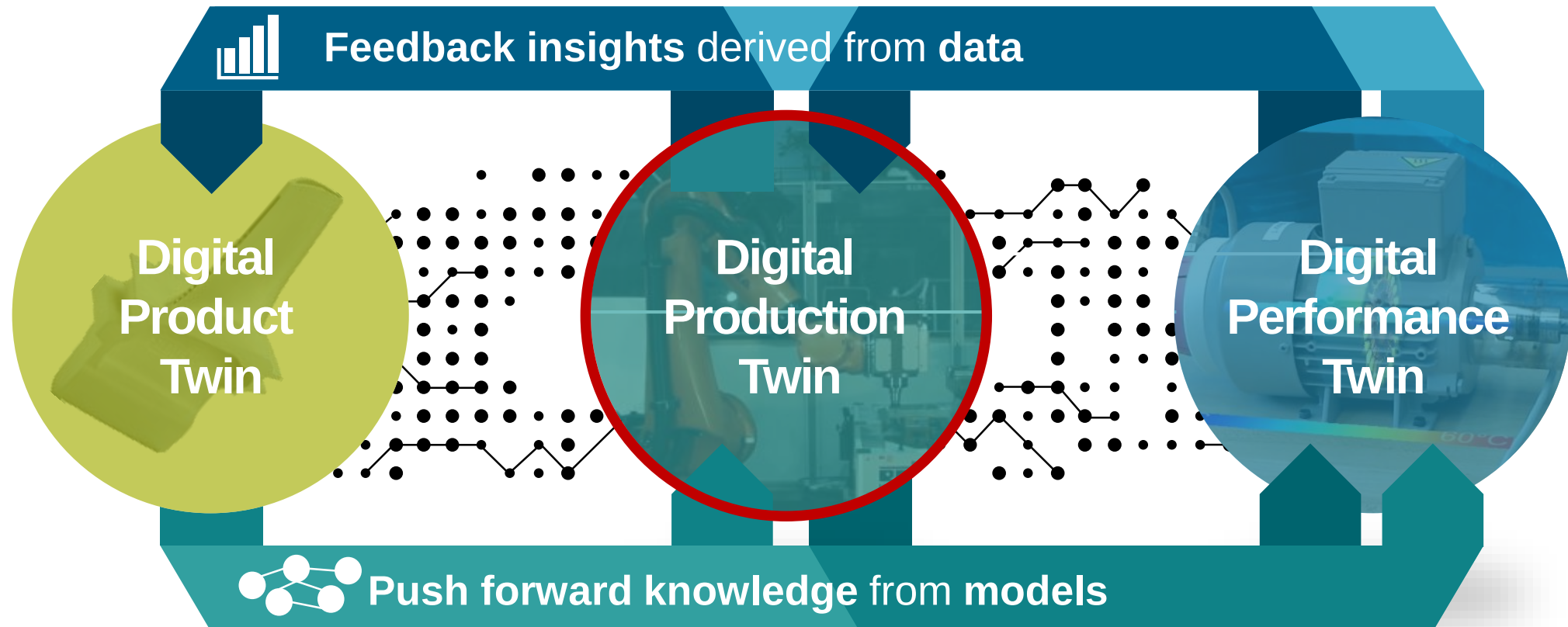
D. Hartmann, S. Gavranovic (2017): [Disrupting Computer Aided Engineering](#). GTC 2017

D. Hartmann, S. Gavranovic, P. Stelzig (2017): [Accurate Interactive 3D Engineering Simulations](#). NWC 2017

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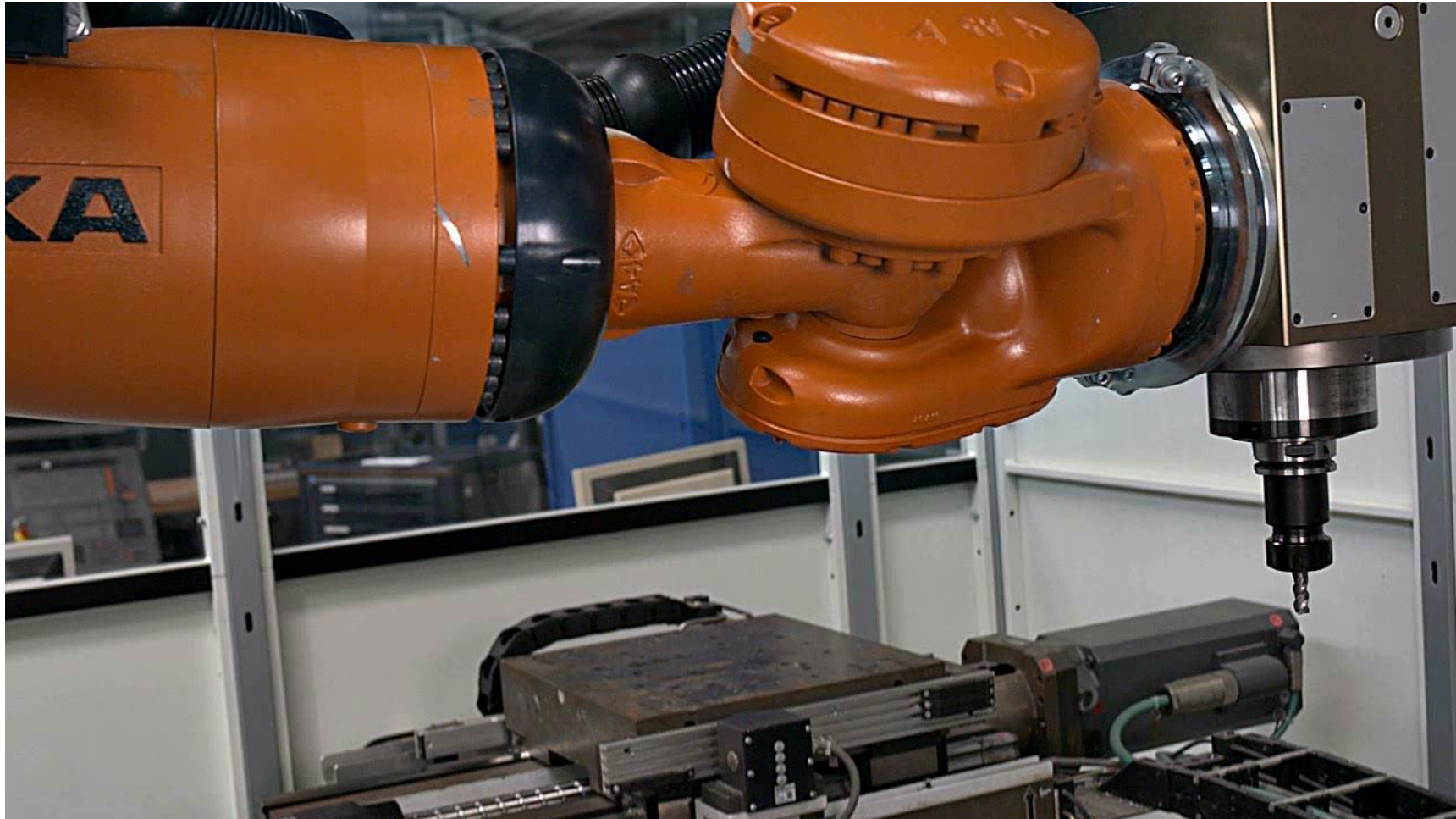
Digital production twin enables robots to mill

Digital twins improve
development, production / construction, and operation.



Digital production twin ...
... enables robots to mill.

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Source: new.siemens.com

Digital production twin enables robots to mill.



Source: [new.siemens.com](https://www.siemens.com/new)



Voxel-based milling process force models

using fine-resolution multiscale geometry models combined with simple heuristic force models



GPU parallelization

introducing state-of-the art computer graphics libraries into manufacturing process simulation



Seamless NX CAM to control integration

leveraging and extending novel DF MC SINUMERIK module CC ROCO-Robot Accuracy as well as extending DF PL product NX CAM

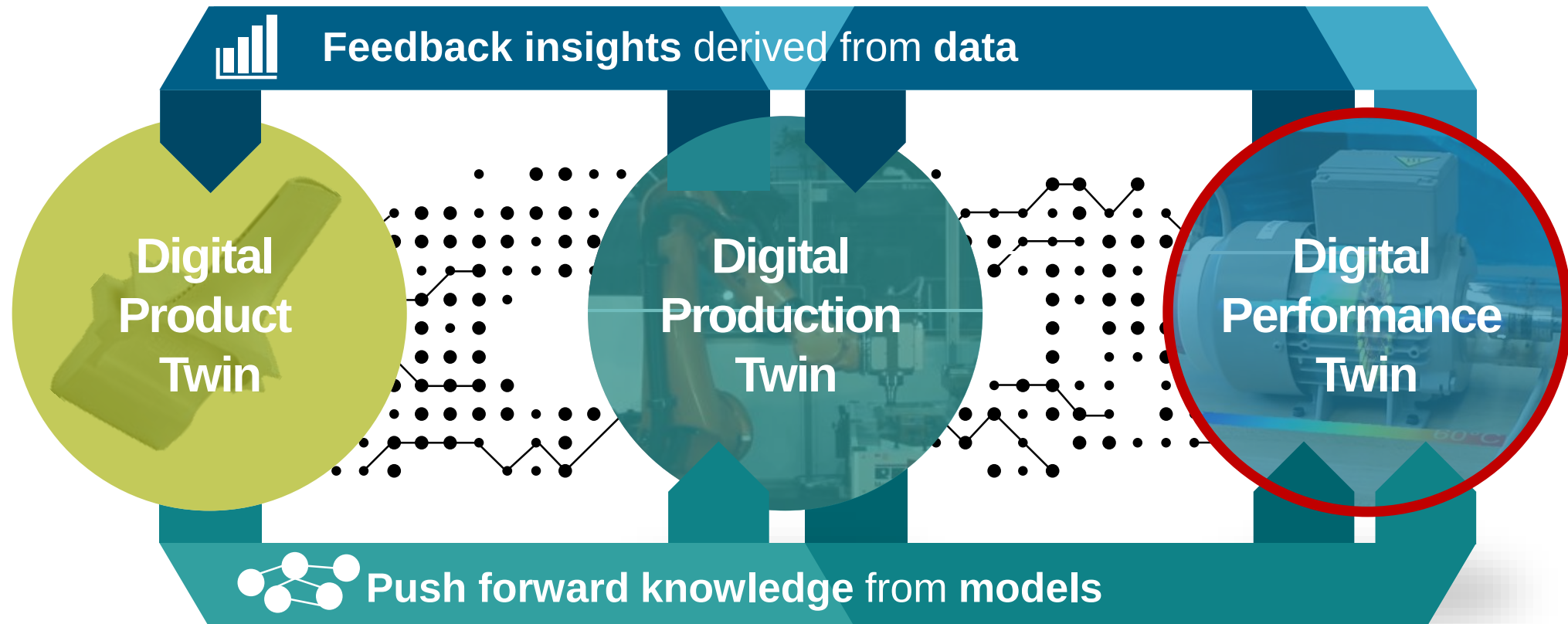
- **10x higher part qualities** enable use of robots for milling
- **Enable lot-1 machining**
- **Novel markets** with predicted growth rates of 16%/y

Sources: D. Hartmann, F. Schnös, S. Tauchmann (2018): [Loading Robots with a Will to Mill](#), Siemens Stories

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Digital performance twin boosts availability

Digital twins improve
development, production / construction, and operation.



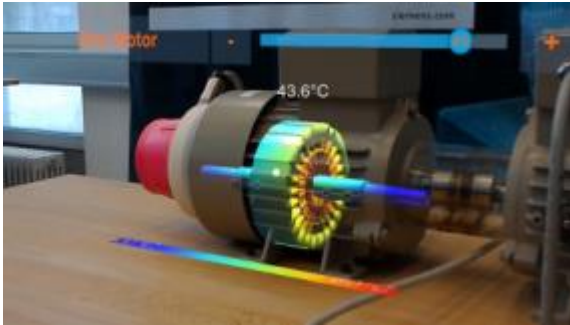
Digital performance twin boosts availability.

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Source: <https://youtu.be/86vkjykbHRM>
new.siemens.com

Digital performance twin boosts availability.



Source: new.siemens.com
<https://youtu.be/86vkjykbHRM>



Model order reduction based on engineering models

speeding up simulation by a factor of 10 000x combining machine learning and simulation



Continuous calibration in the loop

of the digital twin combined with uncertainty quantification allowing secure operation at the limit



Immersed user experience

combining state of the art mixed reality technologies with online simulation and boosting efficiency

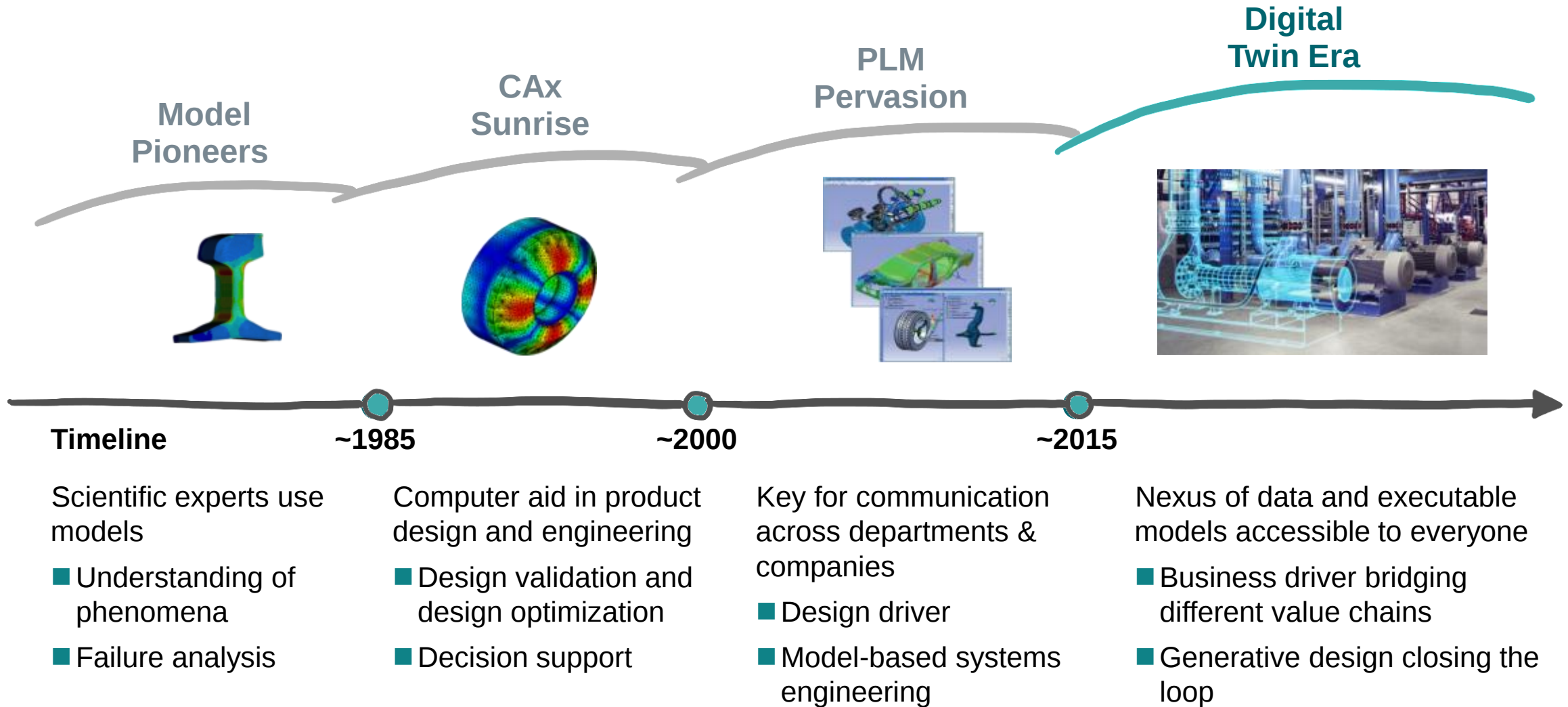
- **Online capable simulation models** without add. effort
- **Higher availability** by 20% reduction of stop times
- **Save costs** of up to 200k€/h

Source: D. Hartmann, M. Herz, U. Wever (2018): Model Order Reduction a Key Technology for Digital Twins, [Springer](#)
J. Salazar (2018): Model order reduction of 3D multi-physics simulations with manifold learning, Thesis TUM / Siemens

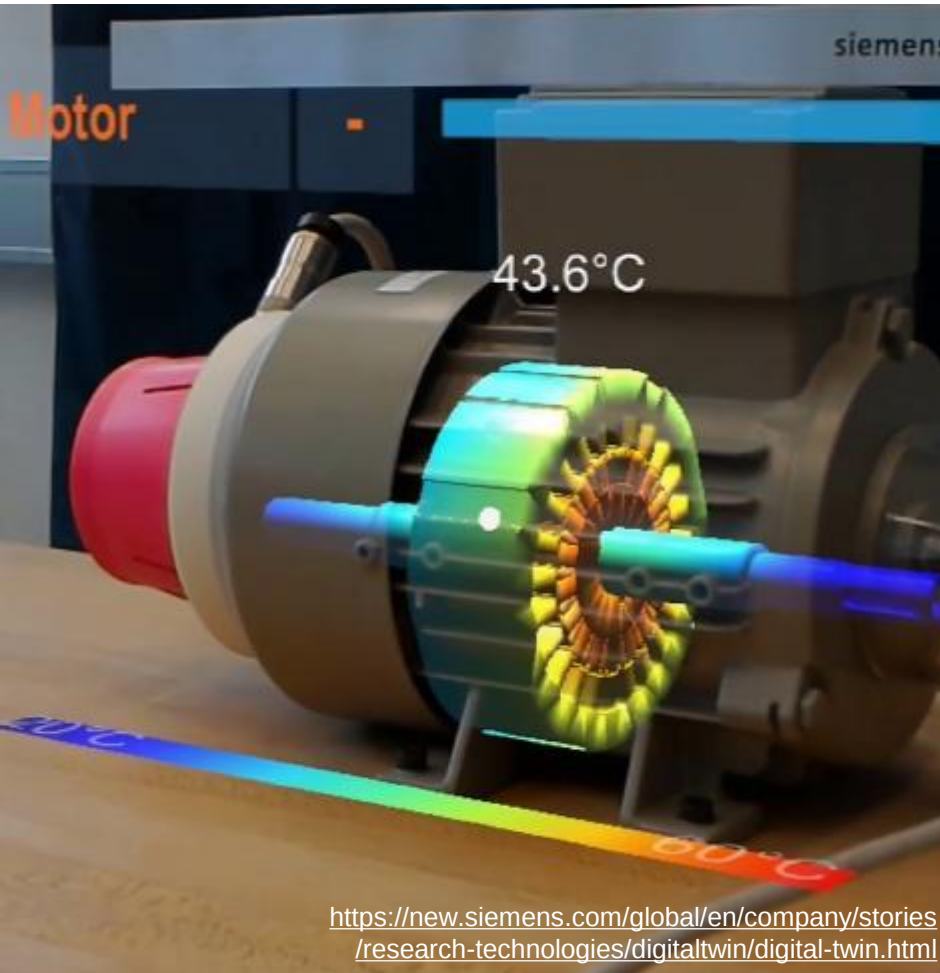
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The age of
pervasive digital
twins is yet to
come

Digital twins are not “new”. Simulation evolved from a trouble shooting tool to key business driver in the form of digital twins.



If you like to know more ...

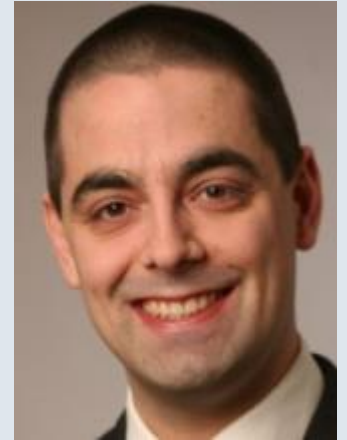


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